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PATENT APPLICATION
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ELECTRONIC INK DISPLAY MEDIA FOR SECURITY AND AUTHENTICATION

Field of the Invention

The present invention relates to display applications and more specifically to using electronic ink displays with smart cards and for enhancing security and authentication.

Cross-Reference to Related Applications

The present application claims priority to and the benefit of U.S. provisional patent applications serial number 60/112,882, filed December 18, 1998, and serial number 60/119,393, filed February 10, 1999. The entire disclosures of these provisional patent applications are incorporated herein by reference.

Background of the Invention

Many documents require authentication, including but not limited to identification papers, currency, labels, mail, time-dated documents, lottery tickets, checks, financial documents, stocks, bonds, corporate documents, legal certificates, wills, credit cards, debit cards, magnetic stripe cards, smart cards, badges, and brand packaging. The advent of high-quality digital printing methods, however, has lowered the barrier for replication of authenticated documents, generating the need for more sophisticated authentication. The inclusion of a display can provide such added sophistication.

To date, documents have relied on a variety of approaches, including complex printed patterns, special papers, unique inks, watermarks, embossed patterns, and metal threads for authentication. Some of these approaches are easily visible, whereas others, such as luminescent inks, may become visible to humans only with the aid of an external device or light source, and still others may be invisible to humans and detectable only by

a machine. Another method is to use fluorescent inks, wherein application of a UV light source will reveal an image. However, common availability of fluorescent inks and UV light sources diminishes some of the value of this approach.

Additional methods of authentication include requiring application of a chemical to reveal an image, rubbing particles or pigments against a textured surface to reveal an image, or printing an image underneath a protective coating as with scratch-off game cards. Additionally, regions that are heat or pressure sensitive, or both, may be placed onto the document, following which, an official wishing to verify authenticity would apply heat or pressure and thereby cause an image to appear. Alternately, two chemicals are printed in proximity, possibly separated by an impermeable coating or other breakable barrier, in which rubbing causes the chemicals to mix and create a visible chemical change. These systems suffer from the fundamental drawback that the effect is irreversible in each region following the test.

Another method, is to embed a hologram into the object requiring authentication; this method is used in credit card applications in particular. The hologram provides visible confirmation of authenticity but it is not replicable by copier machine. Thus, the hologram serves as a security aid. However, this method of authentication requires carefully controlled manufacturing processes and uses materials that may be costly.

Many documents contain secret, privileged, confidential, or sensitive information, for example, intelligence reports, military communiques, descriptions of trade secrets, attorney files, medical records, financial records and personal diaries are only a few types of documents which display such information. Such documents require security. Traditionally, such documents have primarily relied on static methods for security, such as encryption, sealing with a tamper proof seal, or simply being kept under lock and key. Such documents, however, can benefit from an integral and dynamic method for securing the document. The inclusion of a display can provide such benefits.

In addition, with the advent of information storing members (such as RAM and magnetic strips) in wallet-size cards to create 'smart cards', a solution for displaying the information contained therein has become desirable. Typical cards such as credit cards

have a magnetic strip on the rear surface, and a subset of the information contained on the magnetic strip, such as the cardholder name and card number, is embossed physically onto the front surface of the card. This usually suffices for this purpose, since the information on the strip is static. For transaction type cards, such as debit cards, however, there is a need for a means to display the information which is stored on the card, as it is constantly changing. For example, phone cards and access cards may have certain value units which are purchased from some central or distributed authority. These value units (such as tokens, in the case of a subway, or phone minutes) may be actually stored locally on the card and interrogated offline, or the card may carry simply an identification number which is verified at each transaction and correlated with a central balance. The balance remaining on the card, however, is usually not indicated to the user. Prior art solutions to this problem involve systems such as that employed in the Washington DC subway, where a computer daisywheel printer prints the current balance on the card paper surface directly below the prior balance. There are several problems with this solution. First, the user can no longer simply swipe the card through a reader, but must insert it into a large machine in which the printer is housed. Second, cards made with this paper surface are not very durable, the information is not erased but basically crossed out; as a result, the card may be used only so many times before the balance space is filled up. Accordingly, such cards can benefit from the inclusion of a dynamic medium for providing the information contained thereon. The inclusion of a display can provide such benefits.

Both documents that require authentication and documents that require security can benefit from the inclusion of a display. A display can provide a more sophisticated and difficult to reproduce means for authentication. In addition, a display can provide a dynamic and integral means for securing a document. Nevertheless, to date, widespread incorporation of displays has been hindered because such applications generally require flexible displays that consume very little power. Despite much effort directed to developing highly-flexible, reflective display media, there are relatively few examples of displays formed on semi-flexible substrates, and these examples have found only

moderate success. Emissive electroluminescent films and organic light emitting diode films can be deposited on flexible substrates to create flexible displays. However, these devices require continuous power consumption for operation, and thus are not practical for many applications.

Summary of the Invention

Recently the invention of microencapsulated electronic display systems have allowed the use of inexpensive printing methods to pattern or coat a thin layer of microcapsules onto flexible substrates such as paper or plastic, and to form thereby an electronic display medium. The medium is capable of color change and operates by the principle of electrophoresis. Such displays overcome many of the disadvantages associated with the use of displays in document authentication applications and secure document applications. The present invention provides a novel authentication system, a novel system for secure documents, and a novel smart card, each of which utilize electrophoretic displays.

The present invention provides a secure document, an authenticating marker, and methods for authenticating and securing documents that employ a highly-flexible, reflective display which can be manufactured easily, consumes little (or in the case of bistable displays, no) power, and can, therefore, be incorporated into a variety of security and authentication applications. The invention can provide an authentication device that is not easily noticeable or, conversely, an authentication marker that is noticeable to users, yet in which the authentication image contained therein is not easily made visible. The present invention further provides an authentication marker that is useful for machine-only authentication. The invention features a printable display comprising an encapsulated electrophoretic display medium. The resulting display is flexible. Since the display medium can be printed, the display itself can be made inexpensively.

An encapsulated electrophoretic display can be constructed so that one or more optical states of the display are stable for a substantial length of time. When the display has two states each which are stable in this manner, it is said to be bistable, if more than

two such states are stable, then it is said to be multistable. For the purpose of this invention, the term bistable will be used to indicate a display in which any optical state remains fixed once the addressing voltage is removed. The definition of a bistable state depends on the application for the display. A slowly-decaying optical state can be effectively bistable if the optical state is substantially unchanged over the required viewing time. For example, in a display which is updated every few minutes, a display image which is stable for hours or days is effectively bistable for that application. In this invention, the term bistable also indicates a display with an optical state sufficiently long-lived as to be effectively bistable for the application in mind. Alternatively, it is possible to construct encapsulated electrophoretic displays in which the image decays quickly once the addressing voltage to the display is removed (i.e., the display is not bistable or multistable). As will be described, in some applications it is advantageous to use an encapsulated electrophoretic display which is not bistable. Whether or not an encapsulated electrophoretic display is bistable, and its degree of bistability, can be controlled through appropriate chemical modification of the electrophoretic particles, the suspending fluid, the capsule, and binder materials.

An encapsulated electrophoretic display may take many forms. Typically, an electrophoretic display comprises an electrophoretic display medium in electrical communication with at least one conductive element that effectively forms an electrode. The display medium may comprise capsules dispersed in a binder. The capsules may be of any size or shape. The capsules may, for example, be spherical and may have diameters in the millimeter range or the micron range, but is preferably from ten to a few hundred microns. The capsules may be formed by an encapsulation technique, as described below. Particles may be encapsulated in the capsules. The particles may be two or more different types of particles. The particles may be colored, luminescent, light-absorbing or transparent, for example. The particles may include neat pigments, dyed (laked) pigments or pigment/polymer composites, for example. The display medium may further comprise a suspending fluid in which the particles are dispersed.

The successful construction of an encapsulated electrophoretic display medium requires the proper interaction of several different types of materials and processes, such as a polymeric binder and, optionally, a capsule membrane. These materials must be chemically compatible with the electrophoretic particles and fluid, as well as with each other. The capsule materials may engage in useful surface interactions with the electrophoretic particles, or may act as a chemical or physical boundary between the fluid and the binder.

In some cases, the encapsulation step of the process is not necessary, and the electrophoretic fluid may be directly dispersed or emulsified into the binder (or a precursor to the binder materials) and an effective "polymer-dispersed electrophoretic display medium" constructed. In such display media, voids created in the binder may be referred to as capsules or microcapsules even though no capsule membrane is present. The binder dispersed electrophoretic display medium may be of the emulsion or phase separation type.

Throughout the specification, reference will be made to a 'message.' As used throughout the specification, the term message is intended to include any type of indicia such as a number, text, or an image, alone or in combination, that conveys information. The term message includes, but is not limited to, equations, prices, letters, words, graphics, photos, fingerprints, bar codes, 2D bar codes, and speckle patterns.

In one aspect, the invention features a method of authenticating an object. The method includes the steps of: a) providing an object having an authentication marker disposed on a surface of the object, the marker comprising at least one electrode and an electrophoretic display medium; and b) applying an electric field to the marker to change a reflective optical state of the display medium, thereby displaying authenticity of the object. In one embodiment, an object having an authentication marker comprising a first electrode adjacent a first surface of the display medium and a second electrode disposed adjacent a second surface of the display medium is provided, and an electric field is applied between the first electrode and the second electrode. In another embodiment, an object having an authentication marker comprising a first electrode is provided and the

object is exposed to a validation machine having a second electrode. An electric field is applied between the first electrode and the second electrode. The object can be exposed to an electrostatic head or a charged stylus. An authentication marker can be affixed to a surface of the object.

In one embodiment, an electric field is applied to the marker to change a reflective optical property of the display medium. The electric field can be a direct or an alternating electric field. In one example, a first electric field is applied to the marker, thereby causing the display medium to portray a first reflective optical property, and a second electric field is applied to the marker to change the first reflective optical property of the display medium to a second reflective optical property. The present method can further comprise the step of applying a third electric field to the marker to re-create the first reflective optical property of the display medium.

In another embodiment, an electric field is applied to the marker, thereby causing the marker to become visible. Alternatively, an electric field can be applied to the marker to change an impedance of the display medium, and the impedance of the display medium can be measured to display authenticity of the object. In still another embodiment, an object having an authentication marker can comprise an electrophoretic display medium forming a shutter and message hidden behind the shutter, and an electric field can be applied to open the shutter to expose the image.

In another aspect, the invention features a marker for authenticating an object. The marker includes a conductive substrate and an electrophoretic display medium disposed on the conductive substrate. The display medium is capable of changing a state of the display upon application of an electric field, such that authenticity of the object can be displayed. The display medium can comprise a plurality of microencapsulated electrophoretic particles. The conductive substrate can comprise a first electrode, and further comprise a second electrode disposed adjacent the display medium.

In one embodiment, at least one of the first electrode and the second electrode is patterned to form a message. Alternatively, the display medium can be patterned to form

a message. At least one of the first electrode and the second electrode can be a clear electrode.

In another embodiment, the display medium changes a reflective optical property upon application of an electric field. For example, the display medium can change from a first reflective optical property to a second reflective optical property. Alternatively, the display medium can change impedance upon application of an electric field. The display medium can become substantially transparent upon application of an electric field, and a message hidden behind the display can be exposed.

In another embodiment, the display medium changes a reflective optical property upon application of an electric field. For example, the display medium changes from a first reflective optical property to a second reflective optical property. Alternatively, the display medium changes impedance upon application of an electric field. The display medium can become substantially transparent upon application of an electric field. The authenticatable object can be an item of currency, a stock certificate, a negotiable instrument, a credit card, a debit card, or a smart card.

In still another aspect, the invention feature a method for securing a document. In one embodiment, the steps comprise: a) providing a document comprising at least one electrode and an electrophoretic display medium forming a message; b) applying a first electric field to the display medium to expose the message; and c) applying a second electric field to the document to hide the message. The first electric field is applied by subjecting the document to an electrostatic head or a charged stylus. A preselected current or voltage is applied to the document to expose the message.

In another embodiment, the method includes the steps of: a) providing a document having a message on a surface; b) disposing a shield on the surface of the document, the shield comprising a first clear electrode, an electrophoretic display medium disposed on the first electrode, and a second electrode disposed on the display medium; and c) applying a first electric field between the first electrode and the second electrode to shield the message. According to the present invention, a shield is a means to control or limit the viewing of the message, for example, a shield may allow a message to be reviewed

yet prevent copying by photographic means, a shield may hide or scramble a message, or a shield may restrict the angle from which a message can be viewed.

In one embodiment, the method further includes the step of applying a second electric field between the first electrode and the second electrode to expose the message. In another embodiment, a first electric field is applied between the first electrode and the second electrode sufficient to make the display medium substantially transparent. A second electric field can be applied between the first electrode and the second electrode sufficient to make the display medium substantially transparent.

In another embodiment, a method of securing a document includes the steps of: a) providing a document comprising a message formed of a conductive ink on a surface of the document; b) disposing an electrophoretic display medium adjacent the surface of the document; c) disposing an electrode adjacent the display medium; and d) applying a first electric field between the conductive ink and the electrode to hide the message.

In one embodiment, the method further includes the step of applying a second electric field between the conductive ink and the electrode to expose the message. A first electric field can be applied between the conductive ink and the electrode sufficient to make the display medium substantially opaque. The second electric field can be applied between the conductive ink and the electrode sufficient to make the display medium substantially transparent.

The invention also features a secure document. In one embodiment, the document comprises a conductive substrate, and an electrophoretic display medium forming a message disposed adjacent the substrate. The electrophoretic display medium is capable of exposing the message upon application of a first electric field and capable of hiding the message upon application of a second electric field. The electrophoretic display medium can comprise a plurality of microencapsulated electrophoretic particles.

In another embodiment, a secure document comprises a substrate having a message on a surface, a first clear electrode disposed adjacent the surface of the substrate, an electrophoretic display medium disposed adjacent the clear electrode, and a second electrode disposed adjacent the display medium. Application of a first electric field

between the first electrode and the second electrode makes the electrophoretic display medium substantially opaque and application of a second electric field between the first electrode and the second electrode makes the electrophoretic display medium substantially transparent. The display medium can comprise a plurality of microencapsulated electrophoretic particles.

In still another embodiment, a secure document comprises a substrate comprising a message formed of a conductive ink, an electrophoretic display medium disposed adjacent the substrate, and an electrode disposed adjacent the display medium. Application of a first electric field between the conductive ink and the electrode renders the display medium substantially opaque and application of a second electric field between the conductive ink and the electrode renders the display medium substantially transparent. The display medium can comprise a plurality of microencapsulated electrophoretic particles.

In another aspect, the invention features a sticker display. The electrically active sticker display includes an encapsulated display medium and an adhesive layer disposed on the first surface of the display medium. In some cases, the encapsulated electrophoretic display may be itself sufficiently adhesive to function as a sticker without additional adhesive layers. The display medium comprises an optoelectrically active material. In one embodiment, a transparent layer including an electrode is disposed adjacent a surface of the display medium. In another embodiment, the sticker display further includes a via which extends from the transparent layer to the adhesive layer.

In still another aspect the invention features a wearable object having an authentication marker. Such a wearable object includes an article of clothing including an authentication marker incorporated into the wearable object. The wearable object may further include a controller in electrical communication with the authentication marker. The authentication marker comprises an encapsulated display medium. In one embodiment, the controller is incorporated into the wearable object. In another embodiment, the wearable object comprises a fashion accessory. In another embodiment the wearable object comprises a badge. In still another embodiment, the wearable object

includes an interface for receiving information from another device that can update the authentication or security status of the authentication marker.

The present invention provides an electronic display is integrated into a smart card which is capable of being externally addressed. The display is bistable, reflective, and preferably capable of being printed or laminated directly onto the card. It is capable of being addressed directly by an electrostatic head. In one embodiment, the head embedded directly into the magnetic strip reader/writer. In this embodiment, the card's magnetic strip is read in a single swipe and the display electrostatically addressed. In one embodiment, a laminate is constructed which consists of a rear conductive substrate, a layer of bistable electrostatically addressable ink material (i.e. a microencapsulated electrophoretic display), and a protective top dielectric layer. This structure is then laminated to a typical magnetic strip card, such as a subway access card, on the opposite side of the card as the magnetic strip. A section of the back electrode is left exposed. When swiped in a specially designed reader, the magnetic strip reader can read the data on the card, write new data onto the strip, and on the opposite side of the card, an electrostatic head (10 elements for example) can write data onto the display material, making a single electrical connection to the rear electrode and erasing and addressing the display material with positive and negative potentials relative to the rear electrode. This hardware device which integrates a magnetic reader, writer, and electrostatic addressing head is also a novel construction. The magnetic reader can be used to sense the velocity of the swipe, and control the speed of the addressing. Alternatively, the display can be integrated onto a standard smart card, which is then capable of being addressed externally when inserted into a reader.

In one aspect, the invention features a smart card. The smart card comprises a substrate including an activation device, and an encapsulated electrophoretic display disposed on a surface of the substrate. The activation device provides information to or triggers the encapsulated electrophoretic display to display a message. The activation device can be an information storage device, and the display can show information stored in the information storage device. The information storage device can have information

associated with a subway access card, or financial information for a telephone card, a debit card, a credit card, or the like.

In another aspect, the invention features a device for addressing a smart card. The device comprises an activation device reader, an activation device writer, and a display addressing head. The electrophoretic display can be externally addressable. For example, the electrophoretic display can be addressable with an electrostatic head. In one embodiment, the electrophoretic display is addressable by inserting the card into a reader.

In another aspect, the invention provides a method of addressing a smart card. The method comprises the steps of obtaining an output from an activation device of a smart card; and addressing an encapsulated electrophoretic display of the smart card to display information responsive to the output from the activation device. The invention also provides a method of manufacturing a smart card. In one embodiment, the method comprises the steps of providing a substrate; disposing a magnetic strip on a surface of the substrate; and disposing an encapsulated electrophoretic display on a surface of the substrate.

Brief Description of the Drawings

The invention is pointed out with particularity in the appended claims. The advantages of the invention described above, together with further advantages, may be better understood by referring to the following description taken in conjunction with the accompanying drawings. In the drawings, like reference characters generally refer to the same parts throughout the different views. Also, the drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention.

FIGS. 1A-1C show diagrammatic exploded views of various embodiments of a printed flexible electrophoretic display.

FIGS. 2A-2B show diagrammatic views of various embodiments of display medium that is not bistable.

FIGS. 3A-3C show exploded diagrammatic views of one embodiment of an authentication marker.

FIGS. 4A-4C show exploded diagrammatic views of a second embodiment of an authentication marker.

FIGS. 5A-5D show exploded diagrammatic views of a third embodiment of an authentication marker.

FIGS. 6A-6C show diagrammatic views of various embodiments of an object with an authentication marker.

FIGS. 7A-7C show diagrammatic views of another embodiment of an object with an authentication marker.

FIGS. 8A-8C show exploded diagrammatic views of one embodiment of an authentication marker as a time and/or environment sensitive label.

FIG. 9 shows one embodiment of a wearable authentication object.

FIGS. 10A-10C show exploded diagrammatic views of one embodiment of a secure document.

FIGS. 11A-11C show exploded diagrammatic views of a second embodiment of a secure document.

FIGS. 12A-12B show exploded diagrammatic views of a third embodiment of a secure document.

Detailed Description of the Invention

Throughout the specification, reference will be made to printing or printed. As used throughout the specification, printing is intended to include all forms of printing and coating, including: premetered coatings such as patch die coating, slot or extrusion coating, slide or cascade coating, and curtain coating; roll coating such as knife over roll coating, forward and reverse roll coating; gravure coating; dip coating; spray coating; meniscus coating; spin coating; brush coating; air knife coating; silk screen printing processes; electrostatic printing processes; thermal printing processes; and other similar

techniques. A "printed element" refers to an element formed using any one of the above techniques.

According to the present invention, a substrate or object is provided and an electronic ink is printed onto a surface of the substrate or object. The substrate may be an electrode or conductive layer and the substrate may be patterned. The present invention takes advantage of the physical properties of an electronic ink which permits a wide range of printing and coating techniques to be used in creating an electrophoretic display. Electronic ink layers may be constructed inexpensively, are able to hold an image for long periods of time without drawing energy, can be as flexible as paper, have visual qualities similar to standard printing inks, and have the advantage that they can change color when actuated.

Throughout the specification, the term 'electronic ink' shall refer to a printed layer, possibly patterned or coated, of an electrophoretic display medium operating by any suitable principle known in the art. An electronic ink is an optoelectronically active material which comprises at least two phases: an electrophoretic contrast medium phase and a coating/binding phase. The electrophoretic phase comprises, in some embodiments, a single species of electrophoretic particles dispersed in a clear or dyed medium, or more than one species of electrophoretic particles having distinct physical and electrical characteristics dispersed in a clear or dyed medium. The coating/binding phase includes, in one embodiment, a polymer matrix that surrounds the electrophoretic phase. In this embodiment, the polymer in the polymeric binder is capable of being dried, crosslinked, or otherwise cured as in traditional inks, and therefore a printing process can be used to deposit the electronic ink onto a substrate. Typically, in a microencapsulated electrophoretic display medium, the layer of microcapsules will be in communication with at least one conductive element that effectively forms an electrode.

Electronic inks typically operate through the use of pigments and dyes; alternately an electrophoretic shutter effect may also be employed to achieve an opaque or transmissive state and thereby reveal one or more static indicia printed beneath the ink; such static indicia may be printed using any suitable technique, pigment or dye. Through

the use of uncommon pigments, dyes, or inks, a specific color may be selected that is optically verifiable. By using the method described herein, it is possible to expose this color only inside a validation machine; thus, never revealing the color where it could be replicated by color copier. It is also possible to use specially modified pigments such as luminescent or radiation-excitable pigments, or mixtures of such pigments with traditional pigments. By encasing such special pigments in microcapsules and using the electronic ink system, forgers are required to master not only the production of the pigment but also the economical production of an electrically active ink made from the pigment. If desired, the colors of electronically active and non-active inks may closely match and the reflectivities may be similar. Electronic inks can be printed so that no border is noticeable between active and non-active inks. This is referred to as "color matching" or "color masking". Therefore, a display comprising an electronically active portion may appear as if it is not electronically active when the display is not being addressed but may be activated by addressing the display.

The optical quality of an electronic ink is quite distinct from other electronic display materials. The most notable difference is that the electronic ink provides a high degree of both reflectance and contrast because it is pigment based (as are ordinary printing inks). The light scattered from the electronic ink comes from a very thin layer close to the top of the viewing surface. In this respect it resembles a common, printed image. Thus, electronic ink is easily viewed from a wide range of viewing angles in the same manner as a printed page. Such ink approximates a Lambertian contrast curve more closely than any other electronic display material. Since electronic ink can be printed, it can be included on the same surface with any other printed material. Electronic ink can be made optically stable in all optical states, that is, the ink can be set to a persistent optical state. Fabrication of a display by printing an electronic ink is particularly useful in low power applications because of this stability.

An electronic ink is capable of being printed by several different processes, depending on the mechanical properties of the specific ink employed. For example, the fragility or viscosity of a particular ink may result in a different process selection. A very

viscous ink would not be well-suited to deposition by an inkjet printing process, while a fragile ink might not be used in a knife over roll coating process. Electronic inks are described in more detail in co-pending United States Patent Application Serial No. 08/935,800, the contents of which are incorporated herein by reference.

Referring to FIG. 1A, in one embodiment, a display 1 is created by printing a first conductive layer 2 on a substrate 3, printing an electronic ink 4 on the first conductive layer 2, and printing a second conductive layer 6 on the electronic ink 4. Referring to FIG. 1B, in another embodiment, a display 1 is created by printing a first conductive layer 2 on a first substrate 3, printing an electronic ink 4 on the first conductive layer 2, printing a second conductive layer 6 on a second substrate 3', and configuring the substrates 3, 3' such that the second conductive layer 6 is in electrical communication with the electronic ink 4. Referring to FIG. 1C, in another embodiment, a display 1 is created by printing an electronic ink 4 on a conductive substrate 2', and printing a second conductive layer 6 on the electronic ink 4. Conductive layers 2, 2', 6 may be Indium Tin Oxide (ITO) or some other suitable conductive material. The conductive layers 2, 2', 6 may be applied from a vaporous phase, by electrolytic reaction, or deposition from a dispersed state such as spray droplets or dispersions in liquids. Conductive layers 2, 2', 6 do not need to be the same conductive material. In one embodiment, the substrate 3 is a polyester sheet having a thickness of about 4 mil (about 101 microns), and the first conductive layer 2 is a transparent conductive material such as ITO or a transparent polyaniline. The second conductive layer 6 may be an opaque conductive material, such as a patterned graphite layer. Alternatively, the second conductive layer 6 can be polymeric. The polymer can be intrinsically conductive or can be a polymer carrier with a metal conductor such as a silver-doped polyester or a silver-doped vinyl resin. Conductive polymers suitable for use as a conductive layer include, for example, polyaniline, polypyrole, polythiophene, polyphenylenevinylene, and their derivatives. These organic materials can be colloidally dispersed or dissolved in a suitable solvent before coating.

The electronic ink 4 comprises a plurality of capsules. The capsules may have an average diameter in the range 5 to 500 microns. In a preferred embodiment, the average diameter of the capsules is in the range 50 to 300 microns. In another preferred embodiment, the capsules' average diameter is in the range of 75 to 300 microns. In a particularly preferred embodiment, the capsules have an average diameter on the order of about 100 microns. Capsules this small allow significant bending of the display substrate without permanent deformation or rupture of the capsules themselves. The optical appearance of the encapsulated medium itself is more or less unaffected by the curvature of the display.

One of the benefits of using printing methods to fabricate displays is eliminating the need for vacuum-sputtered ITO by using coatable conductive materials. The replacement of vacuum-sputtered ITO with a printed conductive layer is beneficial in several ways. The printed conductor can be coated thinly, allowing for high optical transmission and low first-surface reflection. For example, total transmission can range from about 80% to about 95%. In addition, the printed conductive layer is significantly less expensive than vacuum-sputtered ITO. Another advantage of the encapsulated electrophoretic display medium is that relatively poor conductors, for example, materials with resistivities on the order of 10^3 - 10^{12} ohms square, can be used as lead lines to address a display element. Another advantage of the encapsulated electrophoretic display media is the low power consumption of bistable display media.

Referring to FIG. 2A, in one embodiment, a display medium 18 that is not bistable comprises at least one capsule 19, each filled with electrophoretic particles 21 and a fluid 22. In the embodiment depicted in FIG. 2A, electrophoretic particles 21 have polymer chain branches 20 which cause one particle 21 to repel another particle 21. In one embodiment, the fluid 22 is dyed to provide a color contrast with the particles 21. When the display medium is addressed, the particles 21 migrate, as a result of electrophoresis, towards an electrode with an opposite charge, thereby displaying the color of the particles 21. Once the display medium is no longer being addressed, the particles 21 repel each other and redistribute within the fluid 22, thereby displaying the

color of the fluid 22. This encapsulated electrophoretic display medium 18 can be printed onto a substrate to form a display. Alternatively, an electrophoretic display that is not bistable can be formed by providing a standard display cell filled with electrophoretic medium that is not bistable.

Referring to FIG. 2B, another display medium 28 that is also not bistable includes at least one microcapsule or cell 29, filled with a metal sol 31 and a clear fluid 32. Metal sol 31 contains particles which are smaller than a wavelength of light. In one embodiment, the metal sol 31 is a gold sol. When an electric field is applied across the microcapsule or cell 29, sol particles 31 agglomerate and scatter light. When the applied electric field is reduced to below a certain level, Brownian motion causes the sol particles 31 to redistribute, and the clear fluid 32 causes the display medium 28 to appear clear.

The flexible, inexpensive electrophoretic display described above is useful in numerous applications. For example, these flexible displays can be incorporated into objects and serve as an authentication marker. Moreover, these flexible displays can be used in applications where paper is currently the display medium of choice. Further, the dynamic nature of electrophoretic displays make them useful for securing documents. The displays can be tightly rolled or bent double. In other embodiments, the displays can be placed onto or incorporated into highly flexible plastic substrates, fabric, paper, or synthetic paper. Since the displays can be rolled and bent without sustaining damage, they form large-area displays which are highly portable. Since these displays can be printed on plastics they can be lightweight. In addition, the printable, encapsulated electrophoretic display of the present invention can maintain the other desirable features of electrophoretic displays, including high reflectance, bistability, and low power consumption. Electrophoretic display media are described in more detail in co-pending United States Patent Applications Serial Nos. 08/819,320, 08/935,800, 09/140,792, 09/140,862 and 09/289,507, the contents of which are incorporated herein by reference.

There are multiple embodiments of electrophoretic display media that provide authentication and/or enhances the security of an object or document. In one class of embodiments, microcapsules are disposed on a conductive substrate that forms an

electrode. No second electrode is provided. In some embodiments, an externally provided second electrode, such an electrostatic head in a validation machine or a charged stylus, actuates the electrophoretic effect. Referring to FIG. 3A, in one embodiment an authentication marker 100 is created by printing a first electrode 103 in a pattern on an electrophoretic display medium 102. The pattern may form a fixed message or may form various messages determined by how the patterned electrode is addressed. In one embodiment, a pattern that may form various messages is a mosaic font design as described in more detail in co-pending United States Patent Application Serial No. 09/359,937, the contents of which are incorporated herein by reference. The first electrode 103 may be ITO or some other suitable conductive material. Alternatively, the first electrode 103 may be applied from a vaporous phase, by electrolytic reaction, or deposition from a dispersed state such as spray droplets or dispersions in liquids. In one embodiment, the display medium 102 comprises an optoelectrically active component 120 and a binder 130 which holds the optoelectrically active component 120 together. The optoelectronically active component 120, for example, can be an encapsulated electrophoretic display material. In one embodiment, the optoelectronically active component 120 is a single encapsulated electrophoretic particle. Alternatively, the optoelectronically active component 120 can be any other suitable display material such as biochromal microspheres or liquid crystals. The binder 130, for example, can be selected from polyurethanes, polyvinylalcohols, gelatins, polyacrylates, polystyrenes, polyvinylbutyrals, polyesters, epoxies, silicones, polycarbonates, their derivatives, and pressure-sensitive urethanes and adhesives.

The display medium 102 changes its display state occurs by electrophoresis. Specifically, when a coating of microcapsules containing an electrophoretic display material is disposed on a conductive electrode, the presence of a second electrode (such as an electrostatic head, charged stylus, or any other suitable agent acting as a second electrode) can cause a field potential to exist across the microcapsules and thereby cause a display state change, such as a color change, in the electrophoretic display medium. There are many means by which this color change may be accomplished, one typical

system operates by electrophoretically moving white electrophoretic particles through a dark dye to either cause white particles to be visible at the top of the capsule or else to drive them to the bottom where they are hidden by the dark dye.

Referring to FIG. 3B, the display medium 102 has a blocking display state 112 that does not reveal the message. The blocking display state may, for example, be opaque, reflective or be the same color as the pattern of the first electrode 103, and thereby hide or obscure the message. Referring to FIG. 3C, application of a first electrical signal to the first electrode 103 changes the display state of the display medium 102 by electrophoresis and thereby causes the message 105 formed by pattern to appear on the display medium 102. In another embodiment, an external second electrode applies a voltage potential across the display medium and an electrical signal to the first electrode which causes the first electrode to change the display state of some but not all of the display medium, and thereby causing a pattern such as "AUTHENTIC" to appear. In one embodiment, the electrical signal causes electrophoretic particles within a capsule containing a fluid to migrate away from the first electrode, thereby displaying the color of the particles. In another embodiment, the electrical signal causes electrophoretic particles within a capsule containing a fluid to migrate towards the first electrode, thereby displaying the color of the fluid. In another embodiment, the capsules may contain more than one variety of electrophoretic particles each variety having different electrophoretic and optical or capacitive properties. In this embodiment, the electrical signal causes each variety of electrophoretic particles within the capsule to migrate to varying amounts and possibly in opposite directions.

Alternatively, the first electrical signal may be used to produce an electrophoretic shutter effect in the display medium 102 to achieve a transmissive state and thereby reveal the message formed by the pattern formed by the first electrode 103. In this embodiment, the pattern formed by the first electrode 103 is colored, reflective or luminescent. Thus, application of an electrical signal provides authentication by revealing a specific color, pattern or visual property that is not normally exposed, and hence, not easily copied. In another embodiment, the shutter effect may be used to mask

a message or a region beneath the display medium 102 that has been printed in a traditional manner with traditional inks, or special luminescent or radiation-excitable inks.

Once an authentication marker is provided, authentication may occur in a variety of ways. In one embodiment, the authentication marker, or object bearing an authentication marker, may be passed through a validation machine, such as beneath a moving magnetic or electrostatic bar or electrostatic head. In one embodiment, the electrical signal is a series of different electrical charges applied to the marker as it is moved, for example alternating positive and negative charges. In one embodiment, this electrical signal creates visible stripes on the display medium. The stripe is read by human eye or an validation machine by optical recognition; to determine authenticity. In another embodiment, an electrostatic head changes the display state of the display medium to a single color, a measurement is then taken of the display state's visual or electrical characteristics to verify the change. By setting the display medium to a specific display state, for example all black, it is possible to either blend the display medium with the rest of the marker or object or to make it purposefully stand out, such as against a white background. This display state can then persist without any further energy until an electrical signal is applied.

In one embodiment, appearance of the message indicates authenticity. The message may be visible to the unaided human eye. In another embodiment, the message is not visible to the unaided eye, rather, a validation machine determines whether the message appears. For example, the display medium 102 may comprise a suspending fluid and electrophoretic particles of substantially the same color. In this embodiment, the application of an electrical signal causes the electrophoretic particles to move by electrophoresis and changes the inductance of the display medium which is determined by a validation machine: this change in inductance indicates authenticity. In one embodiment, the display medium 102 may be bistable and the message 105 will remain until a second electrical signal is applied to the first electrode 103. In another embodiment, the display medium 102 is not bistable and the message 105 will disappear

after the first electrical signal ceases to be applied. In one embodiment, the disappearance of the message, whether by application of a second electrical signal or by cessation of the first electrical signal, indicates authenticity.

If a validation machine performs its authentication test in a visibly isolated way, such as in a hidden chamber, and resets the display medium to its blocking or original display state upon exit, then the display state changing property of the display medium will not be apparent during authentication. Conversely, in another embodiment, the validation machine may provide a window whereby the display state change may be observed.

Referring to FIG. 4A, in one embodiment an authentication marker 100' is created by printing an electrophoretic display medium 102' in a pattern on a first electrode 103'. The pattern may form a fixed message or may form various messages determined by how the patterned electrode is addressed. In one embodiment, a pattern that may form various messages is a mosaic font design. Alternatively, the display medium 102' is printed in registration with another ink, or overprinted by another ink, such that only a specific message or display state, such as color, is visible only when the electrical signal is applied to the display medium 102'. Referring to FIG. 4B, the display medium 102' has a blocking display state 112' that does not reveal the message. The blocking display state may, for example, be opaque, reflective or be the same color of the first electrode 103'. Referring to FIG. 4C, application of a first electrical signal to the first electrode 103' changes the display state of the display medium 102' by electrophoresis and thereby causes the message 105' formed by pattern to appear on the display medium 102'. In another embodiment, the first electrical signal may be used to produce an electrophoretic shutter effect in the display medium 102' to achieve a transmissive state and thereby reveal the first electrode 103'. In this embodiment, an optical property of the first electrode 103', such as color, reflectivity or luminescence, serves to indicate authenticity. In one embodiment, the display medium 102' comprises an optoelectronically active component comprising a capsule filled with a dye and electrophoretic particles of the same color. In this embodiment, the applied electrical signal causes a display state

change by electrophoresis but no color change is visible. Instead, the electrophoretic movement is detected by capacitive means. In short, authentication is provided by applying an electrical signal to confirm the presence of an electrophoretic display medium, either visually or capacitively. Forged documents that lack such a display medium, such as those created by a photocopier, would be thereby identified.

In the embodiments described above, a charged stylus may be provided that acts as a second electrode to address the display. In this embodiment, the stylus may be scanned over the entire display to address it. Alternatively, the stylus may be used as a writing utensil, addressing only specific portions of the display over which it is passed.

In another embodiment, an authentication marker is created by printing an electrophoretic display medium on a first electrode such that neither the display medium nor electrode is patterned. In this embodiment, the change in display state upon application of one or more electrical signals to the first electrodes serves to indicate authenticity. For example, the display state may change to a transmissive optical state to reveal the first electrode, the color or optical state of which indicates authenticity. Alternatively, the display state may not comprise a substantial change in optical state but rather a change in the capacitance of the electrophoretic medium. For example, the display medium may comprise a suspending fluid and electrophoretic particles of substantially the same color. In this embodiment, the application of an electrical signal causes the electrophoretic particles to move by electrophoresis and changes the inductance of the display medium: this change in inductance indicates authenticity.

In another embodiment, an authentication marker or secure document includes a photosensitive structure capable of changing the state of the display in response to a photonic stimulus. In some embodiments the structure is printed. For example, a printed solar cell array has a photovoltaic characteristic which is capable of providing a voltage to switch the state of the display in response to incident photons. Other structures which are sensitive to other radiative ranges (e.g. infrared, ultraviolet, etc.) could also be printed onto a substrate with the display. In other embodiments, a solar cell may provide power to the display.

In another class of embodiments, the authentication marker incorporates a second electrode, typically a clear top electrode such as indium tin oxide (ITO) on poly(ehtylene terephthalate). In particular embodiments, the electrophoretic display medium is actuated by an electrical signal that creates a voltage potential across the two electrodes through any suitable means. In one embodiment, an external voltage source creates the voltage potential. In another embodiment, an on-board voltage source, such as a battery or solar cell, creates the voltage potential. In another embodiment, a piezo-electric strip, when affected by mechanical force, creates the voltage potential. The external voltage source may communicate with the electrodes by any suitable means, for example, by charged conductors that are touched to contact pads that are exposed on the surface of the document and connected electrically with the respective electrodes. In still another embodiment, the external voltage source is a battery. In one embodiment, a user pushes a button connected to the battery and the display medium changes color; this color change indicates the presence of the electrophoretic medium and, as a result, authenticity.

Referring to FIG. 5A, in one embodiment, an authentication marker 150 is created by printing an electrophoretic display medium 161 on a first electrode 171 and printing a second electrode 172 on the display medium 161. The electrodes 171, 172 may also be applied from a vaporous phase, by electrolytic reaction, or deposition from a dispersed state such as spray droplets or dispersions in liquids. In one embodiment, the electrophoretic display medium 161 comprises an optoelectrically active component 180 and a binder 190 which holds the optoelectrically active component 180 together. Any and each of the display medium 161, first electrode 171, or second electrode 172 may be printed in a pattern to form a message.

Electrodes 171, 172 may be ITO or some other suitable conductive material. The electrodes 171, 172 do not need to be the same conductive material. In one embodiment, the first electrode 171 is an opaque conductive material, such as a patterned graphite layer. The second electrode 172 is a transparent conductive material such as ITO or a transparent polyaniline. Alternatively, the first electrode material can be polymeric. The polymer can be intrinsically conductive or can be a polymer carrier with a metal

conductor such as a silver-doped polyester or a silver-doped vinyl resin. Conductive polymers suitable for use as the first electrode 171 include, for example, polyaniline, polypyrole, polythiophene, polyphenylenevinylene, and their derivatives.

Referring to FIG 5B, the display medium 161 has a blocking display state 162 that does not reveal a message disposed on or formed by a pattern of at least one of the display medium 161, the first electrode 171, or the second electrode 172. The blocking display state may, for example, be opaque, reflective or be the same color as one or both of the electrodes 171, 172. Alternatively, the blocking display state 162 may be the color compliment of one of the electrodes 171, 172 such that in combination the authentication marker 150 presents a black visual appearance that hides or obscures a message disposed on the other electrode. Referring to FIG. 5C, application of an electrical field between the electrodes 171, 172 changes the blocking display state 162 of the display medium 161 by electrophoresis and thereby causes a message 165 to appear. The message 165 may appear on either of the electrodes 171, 172 or the display medium 161. Alternatively, the message may appear due to a combination of the optical properties of the electrodes 171, 172 or one electrode and the display medium 161. For example, referring to FIG. 5D, the authentication marker 150 comprises a patterned second electrode 172' printed on display medium 161 which in turn is printed on a first electrode 171. The application of an electrical field between the first electrode 171 and the second electrode 172 by electrophoresis causes the display medium to display an image that when viewed through the patterned second electrode 172' reveals the message 'VALID'.

In one embodiment of an authentication marker, initiation of the authentication process first requires a user to enter a code or pass some other suitable security screen. For example, an input device is provided (such as a physical lock or touch sensitive data pad) whereby the user possess the key or enters a code or passes some other suitable security screen, permitting an electrical to be supplied to the authentication marker. The message then appears. In one embodiment, authentication marker can also supply an opposite voltage after a period of time, possibly by means of a timer as

described below, causing the message to disappear until the authentication process is re-executed.

In another embodiment, an authentication marker further comprises a means to affix the authentication marker to an object. The means to affix are any suitable means and include, but are not limited to, an adhesive layer, pass through holes for screws, pegs or the like, and hook-and-loop fasteners.

In another embodiment, an authentication marker is disposed on a object to provide a means for authentication of the object. Referring to FIG. 6A, an authentication marker 200 is disposed on an object 201 by printing a first electrode 210 on the object 201, and printing an electrophoretic display medium 220 on the first electrode 210. Alternatively, the first electrode 210 may be applied from a vaporous phase, by electrolytic reaction, or deposition from a dispersed state such as spray droplets or dispersions in liquids. Alternatively, the authentication marker 200 may be affixed to the object 201, for example by an adhesive layer on the marker. The object 201 may be any object that may benefit from authentication. Referring to FIG. 6B, in another embodiment, an authentication marker 200' is disposed on an object 201' by printing a first electrode 210' on the object 201', and printing an electrophoretic display medium 220' over the first electrode 210' and printing a second electrode 230' on the display medium 220'.

The first electrode 210, 210' may be any suitable conductive material such as those described above. The electrodes 210', 230' do not need to be the same conductive material. In one embodiment, the second electrode 230' is a transparent conductive material such as ITO or a transparent polyaniline. The electrode 210, 210' may be an opaque conductive material, such as a patterned graphite layer. Alternatively, the first electrode 210, 210' can be polymeric. The polymer can be intrinsically conductive or can be a polymer carrier with a metal conductor such as a silver-doped polyester or a silver-doped vinyl resin. Conductive polymers suitable for use as an electrode include, for example, polyaniline, polypyrole, polythiophene, polyphenylenevinylene, and their

derivatives. These organic materials can be colloidally dispersed or dissolved in a suitable solvent before coating.

In one embodiment, the display medium 220, 220' comprises an optoelectrically active component and a binder which holds the optoelectrically active component together. The optoelectronically active component, for example, can be an encapsulated electrophoretic display material. In one embodiment, the optoelectronically active component is a single encapsulated electrophoretic particle. Alternatively, the optoelectronically active component can be any other suitable display material such as biochromal microspheres or liquid crystals. The binder, for example, can be selected from polyurethanes, polyvinylalcohols, gelatins, polyacrylates, polystyrenes, polyvinylbutyrals, polyesters, epoxies, silicones, polycarbonates, their derivatives, and pressure-sensitive urethanes and adhesives.

Referring to FIG. 6C, in one embodiment, the first electrode 211' is not printed on the object 201' but rather it is integrated into the object 201' and an electrophoretic display medium 222' is printed over the first electrode 211'. In one embodiment, the first electrode may be a conductive thread 211'. The thread 211' may be metallic or some other suitable conductive material. The thread 211' may offer a reflective surface sufficient to avoid accurate reproduction by copier machine and may also create an increase in capacitance that is easily detectable. In one embodiment, the display medium comprises a single electrophoretic particle 222'. In one embodiment, the display medium 222' is not visible to the unaided eye; adding a further barrier to forgery of the object.

Ins a1

Referring to FIGS. 7A and 7B, in one embodiment, an object 301 with an authentication marker 300 is created by disposing a first electrode 310 on the object 301 by printing or other suitable means and disposing an electrophoretic display medium 320 on the first electrode 310 by printing or other suitable means. The display medium 320 has a blocking display state 322 that does not reveal a message that indicates authenticity. The message may be disposed on the first electrode 310 or on a surface 350 of the object 301 beneath the first electrode 310. Alternatively, the message may be formed by a pattern formed by the display medium 320 or first electrode 310. The blocking display

state 322 may, for example, be opaque, reflective or a color which hides or obscures the message. Referring to FIG. 7C, a second electrode 330 is used to apply a first electrical field between the electrodes 330, 310. The second electrode 330 may be a charged stylus, an electrostatic head or any electrode adapted to interact with the authentication marker. Application of the first electrical field changes the blocking display state 322 of the display medium 320 by electrophoresis and thereby causes the message 315 to appear. As described above, the change in display state may be a change in the inductance of the display medium 320. Further, as described above, the message may appear as a result of a change in an optical property of the display medium, such as color, reflectivity or luminescence. As described above, the message may also appear as a result of producing an electrophoretic shutter effect in the display medium 320 to achieve a transmissive state which reveals, for example, a message disposed on the surface 350 of the object.

In one embodiment, the second electrode 330 may be in communication with a validation machine 375. The validation machine 375 may serve to indicate authenticity of an object 301 where, for example, the change in display state comprises a change in the inductance of the display medium 320 or a change in an optical property of the display medium 320 not readily discernable by the unaided human eye. In one embodiment, an authentication marker 300 may be in communication with a timer 380. The timer 380 may cause a message to disappear, appear or be erased after a set time or after a set time following a triggering event such as authentication execution or attempted authentication.

In one embodiment, the timer comprises a junction formed of p-type semiconductor (e.g., boron doped) and an intrinsic or undoped semiconductor. In this device, current does not flow. However, if the intrinsic semiconductor becomes n-doped (i.e., if the semiconductor has extra electrons available from the valence shell of dopant atoms), then current could flow from the n-doped region to the p-doped region. Normally, intrinsic semiconductors become n-doped if doped with phosphorous. In another embodiment, the timer 380 comprises a beta particle emitting substance, such as tritium, embed or placed in close proximity to the intrinsic region. In another

embodiment, the timer 380 comprises the intrinsic region of an n-doped-intrinsic junction semiconductor treated with an alpha particle emitter, such as Helium-5, to convert it to a p-doped region. Over time, a non-conducting junction with an alpha or beta particle emitter embedded in its intrinsic region transforms into a diode-type junction which passes current, thereby acting as a timer.

In another embodiment, the timer 380 is a p-n junction semiconductor sensitive to light, such that light forces a current to flow from the n-region to the p-region. The timer 380 can include a tritiated phosphor in a Zener diode and a display. A Zener diode is a diode designed to survive reverse breakdown. Light applied to the Zener diode through the tritiated phosphor increases the breakdown voltage of the Zener diode. When the tritiated system wears out, the Zener diode breakdown voltage decreases and an electrical field is applied between the electrodes 330, 310.

In one embodiment an authentication marker may be a time and/or environment sensitive label that authenticates the quality or state of the object labeled. Referring to FIG. 8A, a time and environment sensitive label 401 is created by printing an electrophoretic medium 420, with a blocking display state 422, on a first electrode 410, printing a second electrode 430 on the display medium, and disposing, by printing or other suitable means, a timer 480 and a transducer 490 in communication with the first electrode 410. Referring to FIG. 8B, the timer 480 may after a set time initiate the application of an electrical filed between the electrodes 410, 430 that changes the blocking display state 422 to reveal a message 425. The message may indicate that the labeled item is at the peak of quality and ready to be used or it may indicate that an item is past its expiration date and should be discarded. The transducer 490 may after a set environmental condition initiate the application of an electrical filed between the electrodes 410, 430 that changes the blocking display state 422 to reveal a message. The message may indicate the labeled item has been exposed to conditions that would destroy its quality and should be discarded. Referring to FIG. 8C, the transducer 490 and timer 480 are in electrical communication and may after a set time after a set environmental event initiate the application of an electrical filed between the electrodes 410, 430 that

changes the blocking display state 422 to reveal a message 426. The message may indicate that a certain action should be taken to preserve the quality of the labeled item, as in the case of turning wine bottles, or that the labeled item should be replenished, as in the case of refilling a prescription a set time after a bottle is opened based on the daily dosage.

In still another embodiment, authentication markers are incorporated into clothing to provide a wearable authenticatable object. Referring to FIG. 9, a wearable authenticatable object 502 is embodied as a patch on the arm 504 of a jacket 500 providing identification 506 or other information. In one embodiment, the wearable object 502 includes a controller 508 in electrical communication with the display 510 of an authentication marker comprising a encapsulated, electrophoretic display medium and a backplane. The display medium is printed onto the backplane. The backplane further includes electronics necessary for addressing the display 502. In some embodiments, the wearable object is in communication with at least one device that provides data for display, such as a updates of authentication or security status. In these embodiments, the data device communicates information to the display which then displays the information for the wearer.

Wearable authenticable objects can be incorporated into other wearable items such as badges, jackets, hats, shoes, socks, pants, underwear, wallets, key chains, shoe laces, suspenders, bracers, ties, buttons, buckles, shirts, skirts, dresses, glasses, contact lenses, watches, cuff links, wallet chains, belts, backpacks, briefcases, pocket books, gloves, raincoats, watchbands, bracelets, overcoats, windbreakers, vests, ponchos, waistcoats, or any other article of clothing or fashion accessory.

The invention also features a secure document. Referring to FIGS. 10A-C, in one embodiment, a secure document 1000 comprises a conductive substrate 1110, and an electrophoretic display medium 1120 forming a message 1115 disposed on the substrate 1110 by printing or other suitable means. As described above, the display medium 1120 may comprise a plurality of encapsulated electrophoretic particles, the display medium may be bistable or not bistable. The conductive substrate 1110 can comprise ITO or any

suitable conductive material. The display medium 1120 has a blocking state 1122 that hides or obscures the message 1115. Referring to FIG. 10B, an "hidden or obscured" message may comprise a false message 1114. For example, the false message may be erroneous information that nevertheless appears reliable. The message 1115 remains obscured until a user enters a code or passes some other suitable security screen, permitting a correct electrical signal to be supplied to the display medium 1120. The code may be the voltage characteristics of the electrical signal itself. In one embodiment, an input device specifically adapted to interact with the substrate 1110 is provided. Referring to FIG. 10C, application of a correct electrical signal to the substrate 1110 reveals the message 1115. Application of the correct electrical signal changes the blocking display state 1122 of the display medium 1120 by electrophoresis and thereby causes the message to appear. As described above, the change in display state may be a change in the inductance of the display medium 1120. Further, as described above, the message may appear as a result of a change in an optical property of the display medium 1120, such as color, reflectivity or luminescence. In one embodiment the display medium is not bistable and the message disappears after application of the correct electrical signal ceases. In another embodiment, the substrate 1110 is in electrical communication with a timer that may cause the message 1115 to change to a false message, disappear, appear or be erased after a set time or after a set time following a triggering event such as application of a correct electrical signal or attempted application of a correct electrical signal.

Referring to FIGS. 11A-C, in another embodiment, a secure document 1200 comprises a substrate 1210 having a message 1215 on a surface 1211, a first clear electrode 1230 printed on the surface 1211 of the substrate 1210, an electrophoretic display medium 1220 printed on the first electrode 1230, and a second clear electrode 1250 printed on the display medium 1220. In another embodiment, the electrophoretic display medium 1220 is first coated in volume onto rolls of a conductive layer which serves as the first electrode 1230 and then that layer is laminated or adhered to the substrate 1210. As described above, the display medium 1220 may comprise a plurality

of encapsulated electrophoretic particles, the display medium may be bistable or not bistable. The display medium 1220 has a blocking display state 1222 that hides or obscures the message 1215. The message 1215 remains obscured until a user enters a code or passes some other suitable security screen, permitting a correct electrical signal to be supplied to the display medium 1220. Referring to FIG. 11B, application of a correct first electric field between the electrodes 1230, 1250 changes the blocking display state 1222 of the display medium 1220 by electrophoresis and thereby causes the message to appear. As described above, the change in display state may be a change in the inductance of the display medium 1220. Further, as described above, the message may appear as a result of a change in an optical property of the display medium 1220, such as color, reflectivity or luminescence. As described above, the message 1215 may also appear as a result of producing an electrophoretic shutter effect in the display medium 1220 to achieve a transmissive state which reveals the message 1215 disposed on the surface 1211 of the substrate 1210. Referring to FIG. 11C, application of a second electric field between the electrodes 1230, 1250 changes the display state of the display medium 1220 by electrophoresis back to the blocking state 1222 or some other state which hides or obscures the message 1215. In another embodiment, after a user has read the message, the document 1200 is fed into a suitable machine, such as an electrostatic printer, and the electrostatic medium is erased, leaving no physical record of the message that was read. In another embodiment, a timer in electrical communication with at least one of the electrodes 1230, 1250 may cause the message 1215 to change to a false message, disappear, appear or be erased after a set time or after a set time following a triggering event such as application of a correct electrical signal or attempted application of a correct electrical signal.

Referring to FIGS. 12A-12B, in still another embodiment, a secure document 1300 comprises a substrate 1310 comprising a message 1315 formed of a conductive ink 1317, an electrophoretic display medium 1320 printed on the substrate 1310, and an electrode 1330 printed on the display medium 1320. The conductive ink 1317 may be silver ink. The display medium 1320 has a blocking display state 1322 that hides or

obscures the message 1315. The message 1315 remains obscured until a user enters a code or passes some other suitable security screen, permitting a correct electrical signal to be supplied to the display medium 1320. Referring to FIG. 11B, application of a correct first electric field between the conductive ink 1317 and the electrode 1315 by electrophoresis changes the display state of the display medium 1320 and message 1315 appears, as by any of the means described above.

The smart card of the present invention comprises a substrate including an activation device, and an encapsulated electrophoretic display disposed on a surface of the substrate. The activation device provides information to or triggers the encapsulated electrophoretic display to display a message. The activation device can be an information storage device, and the display can show information stored in the information storage device. The information storage device can have information associated with a subway access card, or financial information for a telephone card, a debit card, a credit card, or the like. For example, the activation device can be a magnetic strip, a magnet, an electrical or mechanical contact, an internal or external integrated circuit, or an RF coil. The information storage device can be an integrated circuit which can include a controller and/or RAM chip.

In one embodiment, the activation device is disposed on a rear surface of the substrate and the electrophoretic display is disposed on a front surface of the substrate. In one embodiment, the encapsulated electrophoretic display comprises an electrode, an electrophoretic display medium disposed adjacent the electrode, and a dielectric layer disposed adjacent the display medium. In one embodiment, a portion of the electrode is exposed for making electrical contact. In another embodiment, the electrophoretic display comprises a first electrode, an electrophoretic display medium disposed adjacent the first electrode, and a second clear electrode disposed adjacent the display medium. In one embodiment, the encapsulated electrophoretic display comprises a microencapsulated electrophoretic display medium. In another embodiment, the electrophoretic display comprises a plurality of polymer dispersed electrophoretic display particles. In one

embodiment, the encapsulated electrophoretic display is printed on the substrate. In another embodiment, the electrophoretic display is laminated on the substrate.

In one embodiment, the smart card further includes a device for addressing the card. The device comprises an activation device reader, an activation device writer, and a display addressing head. In one embodiment, the display addressing head comprises an electrostatic head. In one embodiment, the electrostatic head is capable of applying a first electric field to an encapsulated electrophoretic display of the smart card to erase a message on the display, and a second electric field to the electrophoretic display to create a message on the display. In another embodiment, the writer is capable of adding data into an activation device of a smart card. In another embodiment, the reader is an information storage device reader and the writer is an information storage device writer. In one embodiment, the reader is a magnetic strip reader and the writer is a magnetic strip writer.

The invention also provides a method of addressing a smart card. The method comprises the steps of obtaining an output from an activation device of a smart card; and addressing an encapsulated electrophoretic display of the smart card to display information responsive to the output from the activation device. In one embodiment, obtaining an output comprises reading an output from the activation device. In one embodiment, obtaining an output comprises reading an output from an information storage device. In another embodiment, the method further comprises the step of writing data into the activation device. In still another embodiment, addressing the encapsulated electrophoretic display comprises addressing the encapsulated electrophoretic display to display financial information. In still another embodiment, addressing the encapsulated electrophoretic display comprises addressing the encapsulated electrophoretic display with an electrostatic head.

The invention also provides a method of manufacturing a smart card. In one embodiment, the method comprises the steps of providing a substrate; disposing a magnetic strip on a surface of the substrate; and disposing an encapsulated electrophoretic display on a surface of the substrate. In one embodiment, the encapsulated

electrophoretic display is disposed on a surface of the substrate by laminating an assembly of an electrode and an encapsulated electrophoretic display medium on the substrate. In another embodiment, the encapsulated electrophoretic display is disposed on a surface of the substrate by laminating an assembly of an electrode and a plurality of microencapsulated electrophoretic particles. In another embodiment, an encapsulated electrophoretic display is disposed on a surface of the substrate by printing the electrophoretic display.

In another embodiment, the method of manufacturing a smart card comprises the steps of providing an activation device; laminating the activation device inside a substrate; and disposing an encapsulated electrophoretic display on a surface of the substrate. In one embodiment, the encapsulated electrophoretic display is disposed on a surface of the substrate by laminating an assembly of an electrode and an encapsulated electrophoretic display medium on the substrate. In another embodiment, the encapsulated electrophoretic display is disposed on a surface of the substrate by laminating an assembly of an electrode and a plurality of microencapsulated electrophoretic particles. In another embodiment, the encapsulated electrophoretic display is disposed on a surface of the substrate by printing the electrophoretic display. In another embodiment, the method further comprises the steps of providing a first electrode, printing an encapsulated electrophoretic display medium on the first electrode, and disposing a second clear electrode on the display medium. In still another embodiment, the method further comprises the steps of providing an electrode, printing an encapsulated electrophoretic display medium on the electrode, and disposing a dielectric layer on the display medium.

The above authentication markers, objects with authentication markers, secure documents, and smart cards, may also be combined with on-board logic or printed logic, to provide more elaborate authentication and security schemes. For example, in one embodiment, the marker, object or secure document is provided with , a grid of exposed contact pads. In this embodiment, only when the correct pads are supplied with the correct signal will the circuit permit sufficient voltage to flow to the display medium to

cause a detectable change of the display state, and, for example, reveal a message or a sequence of messages.

While the invention has been particularly shown and described with reference to specific preferred embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.